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Prediction of the production of oil palms (*Elaeis guineensis* Jacq.) by inflorescences and bunches counting method in the Dabou region (Côte d'Ivoire)

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***Abstract*— *Knowledge of the expected production for the next six months allows the managers of agro-industrial plantations of oil palms to better organize their technical and financial management. However, the estimation methods must be easy to apply, yet sufficiently accurate. This study was initiated in order to contribute to the development of a model for the estimation of oil palm production on the one hand and to evaluate the sensitivity of the method face the data necessary for this forecast. These data are of two types: the actual production data and the inflorescence and bunch count data. The experiment was carried out on the experimental station Robert-Michaux of the CNRA of Dabou, located in the South-East of the Côte d'Ivoire. The proposed methodology is based on the duration of plan formation and maturation. It takes 5.5 to 6 months between the exit of the female inflorescence and the harvest of the corresponding ripe bunch. Counting of bunches and female inflorescences in the crown provides information on the number of rips bunches to be harvested in the next six months. The evolution of the average weight of bunches harvested previously makes it possible to predict the average weight of bunches that will be harvested during the same period. The model makes it possible to estimate the tonnage of production for the next six months provided that, for a plantation unit, it can be applied to representative samples of the whole. The yield is translated into production at different scales taking into account planting density. The estimated production variations and those of the previous production make it possible to estimate production in the months to come. The results are very satisfactory, with error accuracy of 9 %. They demonstrate the economic and technical interest of such a method in the case of production sites with little information on the conditions of oil palm cultivation.*

Keywords*— *Production forecast, yield, inflorescences, bunches, oil palm, Dabou.

I. INTRODUCTION

Today, estimated at 831 million, the African population is expected to reach 3.8 billion by the year 2100. These demographic changes overwhelm deep environmental changes, due to climate change, which in the region where extensive agriculture is dominant; will negatively impact agricultural production (Wheeler and von Braun, 2013; Challinor *et al*., 2014; Leroux, 2015). In this context of risks of food insecurity, it is essential to improve the means of monitoring agricultural production to face the challenges of development and reduce the vulnerability of the populations. The forecasting of crop productivity is thus a strategic challenge for the developing countries both in terms of food security (autonomy) but also economic (mastery, control and optimization of the volumes produced). It is therefore increasingly important in developing countries and, as in developed countries, to forecast agricultural yields accurately and punctually at regional and even national levels (Meyer-Roux, 1990). Forecasting crop yields is an exercise to prepare and disseminate quantitative or qualitative information about the expected yield of a crop before harvest. Production forecasts are of particular importance in food security estate (FAO and AFRISTAT, 2000) in developing countries where climate disasters sometimes occur. Its importance lies in its role as an early warning system to monitor the situation of food supply by evaluating production that may be available.

As in the case of developing countries, the Ivorian economy relies mainly on agriculture, particularly the exploitation of industrial crops (cocoa, oil palm, coffee, rubber, etc.). Since

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2007, palm oil, with an annual production of about 400,000 tons, has been the second largest export product after cocoa (1,300,000 tons) (Anonyme, 2012). Palm oil is the most consumed vegetable oil in the world (Koné, 2012) with 42 million tons in 2011, or 25 % of all edible oils.

However, there is often an approximate management of the agricultural operators of the production of oil palm, leading to a mismatch between the volume of production and the means mobilized. This leads to production losses during peaks, resulting from poor synchronization of equipment, seasonal personnel and rolling materials. Knowledge of future yields is of prime importance for the management of an oil palm plantation: preparation of a forecast budget, mobilization of the means of production, appreciation of the quantities of oil produced and establishment of the marketing calendar. However, the estimation method must be easy to apply with sufficient precision.

The proposed method is based on the duration of training and bunch ripping. It takes 5.5 to 6 months between the exit of the female inflorescence and the harvest of the corresponding ripe bunch. Counting of inflorescences and bunches can therefore provide information on the number of ripe bunches that will be harvested in the next 6 months. The study of the evolution of the average weight of bunches previously harvested makes it possible to predict the weight of bunches that will be harvested during the same period. This means that the tonnage of production over the next 6 months can be assessed, provided that the planting unit can be representative of the whole.

The general objective of this study is to partially overcome the uncertainties of supply and demand, and to better control stocks through better mastery of the future production of oil palm. With a view to improving the mastery of oil palm production, the specific objectives of this study are (1) to provide a reliable method for forecasting production in one of the main areas of oil palm production of Côte d'Ivoire and (2) to evaluate the sensitivity of the method to the data required for this forecast.

II. MATERIAL AND METHODS

Study site

Observations were made at the Robert-Michaux experimental station in Dabou, located in South-Eastern of Côte d'Ivoire. Its geographical coordinates are 05°18' north latitude and 04°28' west longitude. It is a research station of the CNRA, with what it implies as rigor in the collection of the data. The soils are desaturated ferralitic tertiary sands. The total area of this station is 4115 ha, presenting a series of 5 harvesting systems (CM: chisel-machete, SS: small sickle, MS: medium sickle, TS: tall sickle and STS: super tall sickle). The trial was randomly implanted on 5 % of the plots of each harvesting system of the station.

Vegetal material

The vegetal material is composed of oil palm hybrids obtained by crossing between *Dura* (female parent) and *Pisifera* (male parent). The *Dura* type is characterized by fruit having a thin pulp and a thick shell. The *Pisifera* type is characterized by a high abortion rate of the fruit and by a shell very thin or squarely absent. The *Tenera* hybrid, called C1001F, from the "La Mé x Deli" crop was used. This vegetal material, characterized by high yield and resistance to *Fusariosis*, comes from the second cycle of recurrent reciprocal selection. This new plant material is currently popularized in all Ivorian oil palm growing areas.

The oil palm is a monoecious and strictly allogamic plant (Cochard *et al.*, 2001). The same individual bears both males inflorescences and female inflorescences. They are born in the axils of the leaves. The two inflorescences, described by Böni *et al*. (1994), are carried on sturdy, erect and compressed peduncle.

The male inflorescence (Figure 1) is formed of an ovoid mass, bearing free flowering spikes, erect, imbricate one above the other. These ears bear the male flowers. In the counting process, male inflorescences were not counted.

The female inflorescence, when young, is enclosed in a spate, recalling the shape of the male spadice, but its peduncle is shorter. On the axis of the inflorescence are inserted female ears whose insertions are made in a spiral. These sessile, linear and ascending ears bear the female flowers (Figure 2). They were used to count inflorescences monthly.

After the natural opening of the spate of the female inflorescence, occur the flowers which will be fertilized, not more than three days later, by the pollen grains of the neighboring trees. The female inflorescence then turns into a bunch (Figure 3), which will reach the stage of maturity 5.5 to 6 months after setting.

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Fig.1: Male inflorescence not taken into account in the counting process

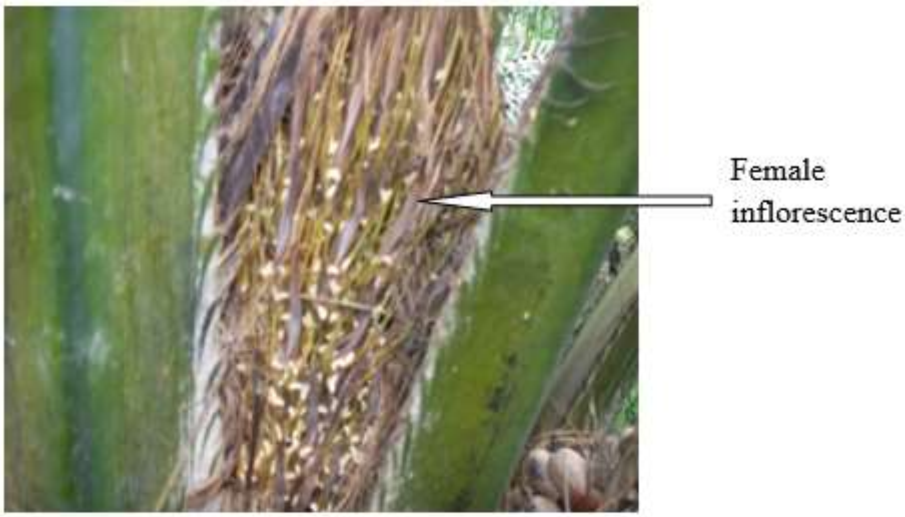

Fig.2: Female inflorescence taken into account in the counting process

Fig.3: Oil palm bunch taken into account during the counting process

Sample choice

In planting, a sample of the order of 5 % of the trees is generally considered sufficient. But to take account of the edaphic variations encountered on a growing unit, this sample must be distributed over the whole extent of the plot. It was therefore systematically chosen one tree out of 20 (for small areas per harvesting system) or one line out of 20 of which all trees were observed (for large areas). In total, these trees or lines were chosen, and distributed over the entire test plot. The same trees or lines were always kept in order to be able to adjust the results obtained after several series of counts compared to the actual results obtained. The lines were marked with an identical mark on the whole station, by metal labels bearing the numbers of the line and the tree. This practice makes it possible to better organize the work of counting, weighing regimes and carrying out systematic control.

Methods

Observation by counting of inflorescences and bunches

An observer fit with a form visits the selected lines of observation and notes for each tree, the number of female inflorescences and bunches present in the crown. He must therefore make the complete turn of the tree to count all bunches and inflorescences open and viable. The observer alternately travels from South to North and from North to South on successively chosen lines. It indicates on the form the number of female inflorescences and bunches observed in the crown of the identified tree. The process ends with the marking of the last male or female inflorescence in anthesis to the painting. These observations were made monthly.

When the trees are aged (from 8 to 10 years), they will have to climb on the foliar peduncle up to the base of the crown to see the young bunches and the female inflorescences. Beyond 12 years, he uses a ladder that he must move to observe the crown on the two opposite sides.

When a tree has neither bunch nor inflorescence, it should be noted 0. However, when a tree is absent, the symbol M (missing) is adopted, not to be confused with a non-producing tree.

Determination of bunches yield

The yield components were determined from individual crops. For this operation carried out every fortnight, a team comprising a harvester, a weigher and a writer clerk visits each identified tree of the plot to collect the production data, according to each harvesting system. The number of bunches per tree (NB/tree) and the weight of bunches per tree (WB/tree), from which the bunch average weight per tree (BAW/tree) and the tonnage of bunches or yield (TB/ha/year). The number of bunches per tree is determined by counting all bunches harvested on each useful tree. The weight of bunches is determined by weighing, using a scale (balance with support) of all bunches harvested by tree. The data collected is used to calculate yield per harvest system (Table 1) from which the yields per unit area are deducted.

Thus, the estimated monthly production is obtained according to the following formula:

TB (tons)/harvesting system = Average value counts * Total trees * BAW.

As for the bunch average weight (BAW), it is obtained from the following formula:

BAW (kg) = total weight of bunches per tree / number of bunches per tree

The annual inventory of the plantation is necessary for the control of the trees actually in production; which will enable the results to be compared with the expected total figures by harvesting system and age groups.

Table.1: Summary of bunch and inflorescence count data

Harvest systems		**Inflorescences**		**Bunches**				**Inflorescences**		**Bunches**				
		1 year	**2 year**	**3 year**	**4 year**	**5 year**	**6 year**	**1 year**	**2 year**	**3 year**	**4 year**	**5 year**	**6 year**	
a	a10	a11	a12	a13	a14	a15	a16	1a= a11/a10	2a= a12/a10	3a =a13/a10	4a =a14/ a10	5a =a15/ a10	6a =a16/ a10	s(1..6)_ a
b	b10	b11	b12	b13	b14	b15	b16	1b =b11/b10	2b =b12/ b10	3b =b13/b10	4b =b14/ b10	5b =b15/ b10	6b =b16/ b10	s(1..6)_ b
c	c10	c11	c12	c13	c14	c15	c16	1c =c11/c10	2c =c12/c10	3c =c13/c10	4c =c14/ c10	5c =c15/ c10	6c =c16/ c10	s(1..6)_ c

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d	d10	d11	d12	d13	d14	d15	d16	1d =d11/d10	2d =d12/d10	3d =d13/d10	4d =d14/d10	5d =d15/d10	6d =d16/d10	s(1..6)_d
e	e10	e11	e12	e13	e14	e15	e16	1e =e11/e10	2e =e12/e10	3e =e13/e10	4e =e14/e10	5e =e15/e10	6e =e16/e10	s(1..6)_e
Totaux	s(col)	s(col m1)	s(col m2)	s(col m3)	s(col m4)	s(col m5)	s(col m6)	s(col m11)	s(col m22)	s(col m33)	s(col m44)	s(col m55)	s(col m66)	stotale_(a...e)

S(col): column sum; S(col mi): sum column month i; S (col mii): sum column i of month i; Stotal (a..e): sum of lines a to e

III. RESULTS

For this study, the estimated production was compared with that actually obtained by the producers for the same period. In order to evaluate the reliability of the forecast model, the correlation coefficient and the mean deviation were calculated.

Figure 4 shows the relationship between the estimated yield and the average yield of the Dabou area over the period 1998 - 2008. The Dabou-scale performance estimation model for this study period provides a highly significant relationship with the observed average yields (R^2 = 0.955***). The prediction error is also very low (less than 5 %). The prediction model found explains for more than 95 %, the average yield of Dabou at this period.

Figure 5 shows the evolution of the monthly production observed and the monthly production estimated from the linear equation. It appears that the two curves (prediction and realization) generally have the same pace. However, there is a strong overestimation of production in the months of July and November. On the other hand, during the months of March to May, there is a very strong underestimation of the monthly production in this study area.

The model generally follows the walk of the monthly production curve observed in the Dabou area. Differences between observed production in this region and estimated production range from -25.7 % (in November) to 25.3 % (in February) as shown in Figure 6. For this study area, the predicted production allows a good estimate. Overall, the differences remain relatively low over the period considered.

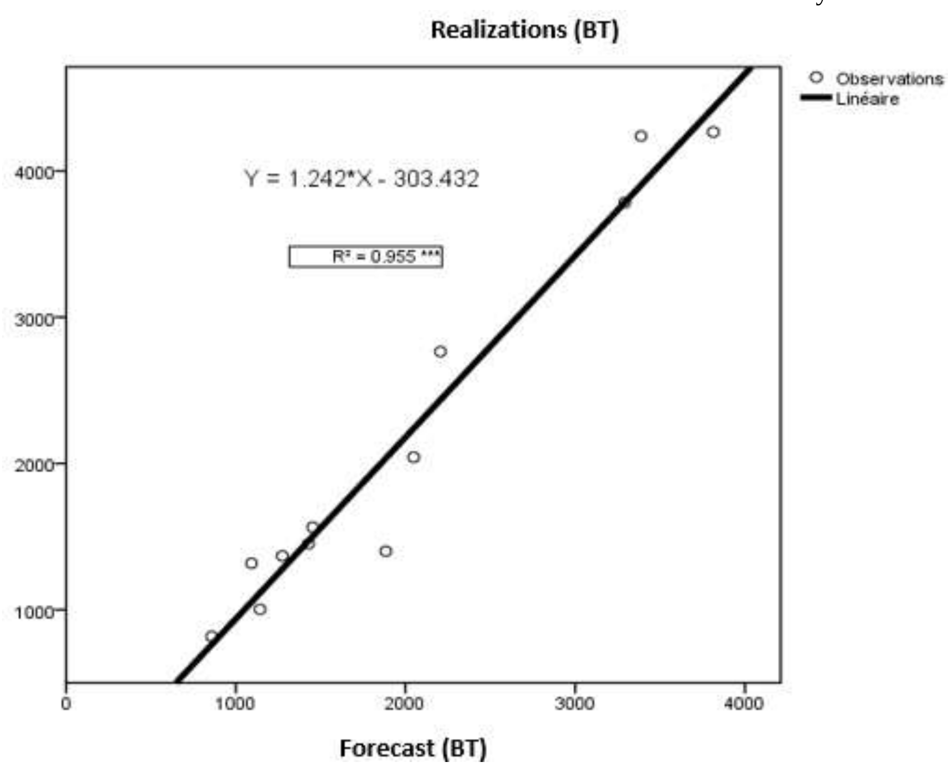

Fig.4: Relationship between the average yield achieved and the estimated yield of inflorescences and bunches counting in the Dabou area

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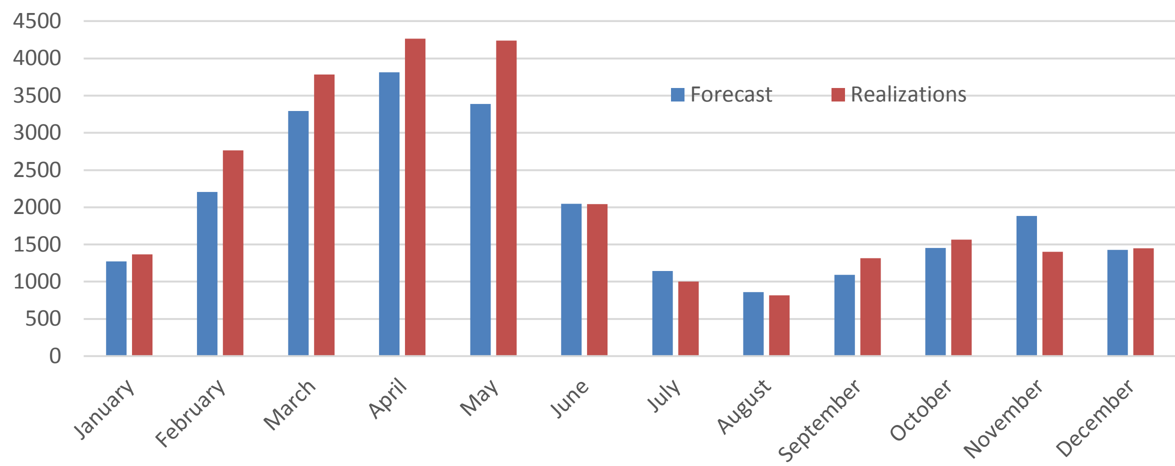

Fig.5: Comparaison between the estimated monthly production and the observed production in the Dabou area for the period 1996 - 2008

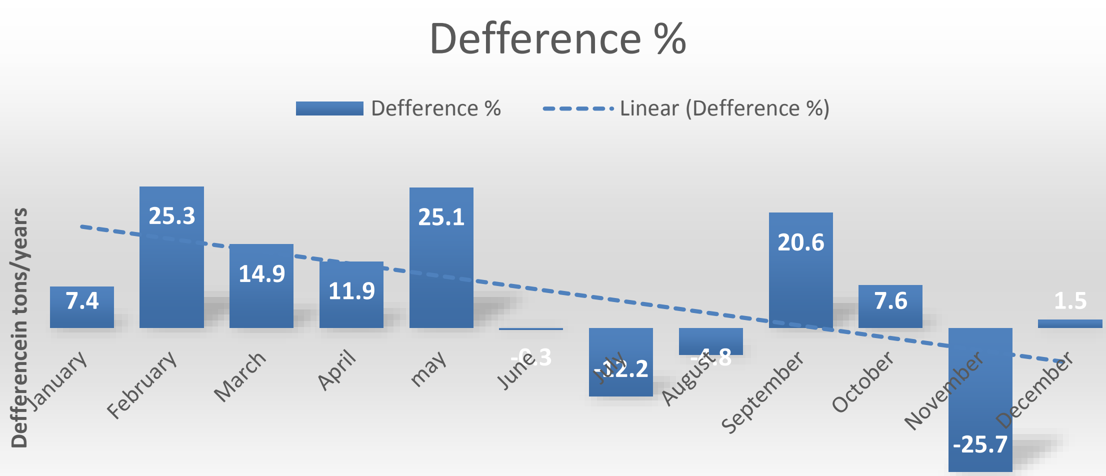

Fig.6: Monthly changes in the variance between forecast and realization (%)

Table 2 shows the productions observed monthly in the Dabou area during the best four years (1998, 1999, 2004 and 2008). In the first half of the year, representing 2/3 of the average annual production, the peak was reached with the month of April (4266 tons of bunches). However, the total average production of the second half (from July to December) represents 1/3 of the annual total. The peak production (1564 tons of bunches) of this semester was recorded during the month of October. Production over the four years ranged from 19.9 (1998) to 28.1 tons/ha/year (1999). The most productive year was 1999.

The precision obtained from the estimated production and the production observed in the study area is presented in Table 3. During this study period, annual production was 23,883 and 26,014 tons of bunches, respectively, for estimated production and observed production. The difference observed between the average observed and estimated production shows that for a site such as that of Dabou, it is rather low (9 %) over the 12 months of the year. For this site, the production forecast model makes it possible to obtain a good estimate of the realizations.

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Table.2: Presentation of the monthly and semi-annual production observed over the best four years

Month	1998	1999	2004	2008	Average	Peak
January	1399,25	623,9	1453,06	1994,84	1368	
February	3722,35	2307,08	2486,4	2541,38	2764	
March	4470,96	4120,58	4273,18	2269,02	3783	
April	4445,93	4847,64	4198,33	3572,24	4266	1
May	4274,87	4892,2	3968,46	3817,5	4238	
June	1846,04	2450,59	1570,32	2302,48	2042	
Total Half-year 1	**15 884**	**19 242**	**17 950**	**16 497**		
July	438,3	1029,85	950,4	1594,82	1003	
August	182,58	692,92	1121,6	1271,3	817	
September	776,46	1610,98	1283,58	1598,74	1317	
October	872,23	1778,94	1566,98	2036,36	1564	2
November	857,8	1689,7	1680,26	1370,7	1400	
December	909,52	2138,56	1858,86	895,34	1451	
Total Half- year 2	**4 037**	**8 941**	**8 462**	**8 767**		

Table.3: Presentation of the accuracy between the estimated production and the production observed in the Dabou area during the four years

	x	y		((y-x)/x)*100
Months	**Forecast**	**Realization**	**y/x**	**Defference %**
January	1274	1368	1,07	7,4
February	2206	2764	1,25	25,3
March	3292	3783	1,15	14,9
April	3814	4266	1,12	11,9
May	3388	4238	1,25	25,1
June	2049	2042	1,00	-0,3
July	1143	1003	0,88	-12,2
August	858	817	0,95	-4,8
September	1093	1317	1,21	20,6
October	1453	1564	1,08	7,6
November	1884	1400	0,74	-25,7
December	1429	1451	1,01	1,5
Total/year	23 883	26 014		9
Area (ha)	2200			
BT/ha	11	12		

IV. DISCUSSION

The results outlined above highlight the importance of the method of forecasting production by counting bunches and inflorescences. The reliable estimate of bunches production therefore uses counting of inflorescences and bunches because, the mean deviations are below 10 %. Forecasting also makes it possible to establish forecast operating accounts, make production forecasts and meet anticipated sales commitments, thus creating a climate of confidence between producers and trading partners. Production forecasts thus contribute to the regulation of the market for agricultural products. Harvest forecasts should be widely disseminated to the relevant national decision-makers and to the cooperating organizations, which are the main applicants. Indeed, according to the FAO (1991), in some countries, the political decision-maker tries to censor the publication of the results of the forecasts, if not to modify them.

This technique, which, despite its supposed subjectivity, makes it possible to obtain reliable forecasts in industrial plantations, remains virtually irrelevant in its application in village plantations.

The production forecast, according to Whisley *et al.* (1986), is part of a series of statistical activities that take place in the following order: crop condition assessment, crop forecasting, crop estimate and final estimate. They are easy to implement with conventional statistical data and with good precision provided they are used in their estate of definition. For Horie *et al*. (1992), the data obtained allow to derive yield forecasts using regression models, empirical rules or informal models based on sectoral experience. This is an effective and reliable method. The precision of forecast depends on the number of fields studied and the parameters measured and the reliability of the regression models for different places and varieties grown.

"Precision" means the difference between the yield forecasts and the production data obtained. Such discrepancies have multiple origins: sampling errors, unexpected harvest damage and specification errors. The definition of precision is retrospective in the sense that it requires a posteriori verification. Other measures of "precision" should then be used, such as the correlation coefficient (r) and the mean deviations (%) between forecast and realization.

The mean deviation makes it easy to assess the degree of similarity between realization and forecast, and also allows measuring the relative error committed on the estimate. A low mean deviation means that the error is small, so the results obtained are reliable (Vossen, 1993). In our study, the 9 % difference was observed between forecast and realization. This value is less than 10 %, below which the estimate is very credible. This highlights the reliability of the forecasting method. As for the correlation coefficient, it allows to describe the percentage of variation of the real yields explained by the forecasts. It makes it possible to explain variations in yield. In other words, the higher the value of r (value tends to 1) the more the predictive model presents the same variations as the real values. The coefficient of variation of 0.955 obtained, explains the smallest variation in yield between the estimate and the realization. The value of any output forecast depends on its accuracy and the speed with which it is available. Routine procedures for rapid processing of data collected during field surveys are therefore particularly important. This approach is of great benefit because the international community is interested in developing an operational model for early crop assessments of main crops (King and Meyer-Roux, 1990).

Since the bunch takes about six months to mature, the production corresponding to this period is visible on the trees. Counting bunches on 5 % of oil palms (one tree in 20 or one lines out of 20) and the average weight of bunches provide an excellent basis for forecasting yields over the next six months. Short-term oil and palm seed contracts can be based on this reliable information provided by the forecast model.

However, yield variability is explained by the fact that crop varieties have some potential for yield. Experimental fields benefiting from optimal conditions make it possible to obtain an approximation of this potential. In reality, yield will be conditioned by relatively stable parameters, such as soil and climate. Crop practices will also condition performance and depend on the skill and skills of farmers. The use of fertilizers and protection against diseases are linked to these skills, but also to economic conditions. Climate change, cropping techniques and land improvement or degradation may well be the main factors influencing yield. These various elements are not independent of one another; some agricultural practices attenuate or, on the contrary, increase variability due to weather conditions (Li, 1990; Liu and Zheng 1990; Benedetti and Rossini 1993; Groten 1993; Maselli *et al.,* 1993).

Table 3, showing monthly production, shows that the first half-year represents 2/3 of the annual average production and the second half-year (from July to December) represents 1/3 of the annual total. The best production of oil palm is characterized by years and months of high productivity. The best seasons of production are at the beginning of the rainy season. The rainy season is still in the first half-year in this region of Dabou. This explains the uneven distribution of oil palm production during the year.

Agricultural yields, particularly, of oil palm, are all affected by a number of factors. Performance prediction systems

simulate physiological processes or provide statistical links between yield and one or more of the factors listed below. It should be noted, however, that all these factors cannot easily be integrated into the yield forecasting systems. Harvest forecasts, both yield forecasts and production forecasts, have become an essential component of food security surveillance and alert systems. Other models, based on the analysis of the relationships between yields and agrometeorological data, should be combined to better adapt to longer areas and longer periods, thus improving the results obtained.

V. CONCLUSION

The method described is a simple means of assessing the output of the semester, but it should be considered as an indicative indicator of management. Indeed, despite relatively high production, they may be slightly overestimated or underestimated, due to seasonal variation, length of maturation and the difficulty of adopting a fully reliable average weight of bunches. It has, however, the merit of easy employment and giving sufficient information. This method of forecasting production by counting inflorescences and bunches appears to be standardized.

However, it is obviously necessary to improve this model of production forecasting. Improving the predictability of oil palm yields depends on a better ability to model the interactions between yields and the variables affecting these yields; such variables affect areas as varied as the climate or the economy. It is only by integrating all the factors involved in this model that forecast errors can be reduced. This condition of integration of number of variables is essential to the development of this technique on a large scale. This model of forecasting will require an extension and a redeployment of the means used with a transfer of the skills acquired since the implementation of these different programs. Additional studies are also essential to obtain the most reliable forecast possible.

REFERENCES

[1] Anonyme, 2012**.** L'huile de palme, l'autre poumon économique de la Côte d'Ivoire - Afrik.com : l'actualité de l'Afrique noire et du Maghreb - Le quotidien panafricain : 1 - 20.

[2] Benedetti R. and Rossini, P., 1993. On the use of NDVI profiles as a tool for agricultural Statistics. The case study of wheat yield estimates and forecast in Emilia Romagna. Remote Sensing of Environment, 45, 311 - 326.

[3] Böni B., Gautier-Beguin D. et Herzof F., 1994 - Le palmier à huile. In: Sempervira, 3, 50 p.

[4] Challinor A. J., Watson J., Lobell D. B., Howden S. M., Smith D. R. and Chhetri, N., 2014. A meta-analysis of crop yield under climate change and adaptation. Nature Climate Change, vol. *4*, 287 - 291.

[5] Cochard B., Adon G., Kouame K., Durand-Gasselin T. et Amblard P., 2001. Intérêts des semences commerciales améliorées de palmier à huile (*Elaeis guineensis* Jacq.). Oléagineux Corps-gras Lipides Vol. 8, (6)**,** 654 - 658.

[6] FAO, 1991. Strengthening National Early Warning and Food Information Systems in Asia and the Pacific: FAO Workshop, FAO, Bangkok, Thaïlande.

[7] FAO, AFRISTAT 2000. Réunion technique sous-régionale sur les méthodes de prévisions de récoltes des cultures vivrières. Rapport de synthèse, Bamako 15-16 mai 2000, 116p.

[8] Groten S., 1993. NDVI-crop monitoring and early yield assessment of Burkina Faso. International Journal of Remote Sensing, 14, 1495 - 1515.

[9] Horie T., Yajima M. and H. Nakagawa, 1992. Yield forecasting. Agricultural Systems, vol. 40, (127), 211-236.

[10] King C. and Meyer-Roux J., 1990. Remote sensing in agriculture: from research to applications. In applications of Remote Sensing in Agriculture, edited by M.D. Steven and J.A. Clark, (London : Butterworths), 377 - 395.

[11] Kone N., 2012. Huile de palme : Un produit rentable et très prisé. Le nouveau consommateur Hebdo. Economie, Publié le lundi 3 décembre 2012, 3 p

[12] Leroux L., 2015. Suivi et Caractérisation des Dynamiques de la Production Agricole en Afrique de l'Ouest par Télédétection à Moyenne Résolution Spatiale.

[13] Li Y., 1990. Estimating Production of winter wheat by remote sensing and unified ground network. II.Nationwide estimation of wheat yield. In *Applications of Remote Sensing in Agriculture* edited by M.D.Steven and J.A.Clark. Butterworths London.

[14] Liu G. and Zheng D., 1990. Estimating Production of winter wheat by remote sensing and unified ground network. I.System Verification. In *Applications of Remote Sensing in Agriculture* edited by M.D.Steven and J.A.Clark.. Butterworths London.

[15] Maselli F., Conese O, Petkov L. and Gilabert M. A., 1993. Environmental monitoring and crop forecasting in the Sahel through the use of NOAA NDVI data. A case study in Niger 1986-89. International Journal of Remote Sensing, 14, 3471 – 3487.

[16] Meyer-Roux J., 1990. Présentation du projet pilote de télédétection appliquée aux statistiques agricoles, Conference on the Appi, of Remote Sensing to Agricultural Statistics, Office for Publications of the E.C.,Luxembourg.
[17] Vossen P., 1993. Forecasting of national crop prodcution, the methodologies developed in the Joint Research Centre in support to the Commission of European Communities. EARSeL Advance in Remote Sensing, 2, 158 - 165.
[18] Wheeler T. and von Braun J., 2013. Climate change impacts on global food security. Science, vol. *341*, (6145), 508 - 513.
[19] Whishley F. D., Acok B., Baker D. N., Fye R. E., Hodges H. F., Lambert J. R., Lemmon H. E., McKinion J. M., Reddy V. R., 1986. Crop simulation models in agronomic systems. Advances in Agronomy, vol. 40, 141 – 208